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RADIATION MEASUREMENTS UTILIZING THE USAF CHEMICAL DOSIMETERS

SCHOOL OF AVIATION MEDICINE
RANDOLPH AIR FORCE BASE, TEXAS

MARCH 1960

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Operation PLUMBOB Final Report

Project 39.1

RADIATION MEASUREMENTS UTILIZING USAF CHEMICAL DOSIMETERS (U)

June 1957

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(Title Unclassified)

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SCHOOL OF AVIATION MEDICINE
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OBJECTIVES

The Operation Teapot program for the correlation of prompt-neutron and prompt-gamma radiation dose with biologic effects was expanded during Operation Plumbbob to include:

1. Prompt-neutron and prompt-gamma angular distribution measurements as a function of distance.
2. Prompt-neutron spectra measurements.
3. The determination of neutron and gamma attenuation coefficients for structural and other shielding materials, including terrain.
4. Correlation of radiation dose measurements with effects in several species of animals.
5. Gamma air-phase propagation measurements.
6. Gamma and neutron depth-dose measurements.

To accomplish the purposes mentioned above, two dosimeter technics were used. One (the water-equivalent, single-phase dosimeter) is sensitive to fast neutrons and gamma rays (1). The other (the 2-phase, fast neutron insensitive gamma ray dosimeter) is less than 1 percent sensitive to fast neutrons but responds to gamma radiation (2). Both systems are sensitive to thermal neutrons but can be shielded with lithium to reduce this response.

These two systems were used primarily for gamma measurements while Hurst's group used the threshold and fission-foil technics (3) for measuring the neutron spectra and tissue dose.

BACKGROUND

At a Dosimetry Conference held by the Civil Effects Test Group (CETG) following Operation Upshot-Knothole, the following points were made:

1. Shot Grablo (250-mm. gun) emphasized the inadequacy of the dosimetry technics being used at that time. Neutron detectors covering various energy ranges were lacking. Gamma-dose measurements in mixed radiation fields were suspect.

2. Accurate and adequate dose measurements should be made simultaneously with radiobiologic experimentation.

3. Basic information concerning the attenuation of weapon radiations in structural materials and light assemblies was incomplete or nonexistent.

4. Laboratory experimentation was not keeping pace with advances in weaponry.

5. More coordination of laboratory research and less frequent test activity were considered necessary.

In part, the Dosimetry Conference fulfilled its mission by establishing a long-range program of objectives for the investigation of radiation dosimetry. By late 1953, Hurst and co-workers had produced a system for measuring neutron flux and spectra. One year later, investigators of the School of Aviation Medicine, USAF, had demonstrated that certain chemical systems were adequate for the measurement of gamma radiation in the presence of fast and thermal neutrons.

In 1954, investigators of the School of Aviation Medicine - in cooperative experimentation at Oak Ridge with Hurst and his associates and at Los Alamos with Harris and his colleagues - demonstrated the reliability and accuracy of the anhydrous chloroform and anhydrous tetrachloroethylene dosimeter systems for measuring gamma rays in the presence of neutrons.

In 1955, Operation Teapot afforded an opportunity to test the above-mentioned systems by comparing their response to gamma radiation with the response recorded by film badges and carbon ionization chambers. These chemical systems proved exceptionally successful in measuring gamma radiation in the presence of fast neutrons during this operation.

However successful the measurements were, it was obvious that several areas required investigation and improvement. The findings were as follows:

1. The anhydrous chloroform and anhydrous tetrachloroethylene dosimeters were still a laboratory curiosity since production technics were crude and reproducibility poor.

2. Field evaluations, utilizing titration technics, were subjective and a more objective evaluation method was needed.

3. The use of plastic blocks wrapped with 0.375-inch lithium metal and 0.020-inch sheet lead as a field shield system was successful but crude. Thus, a new, more refined field shielding system was needed.

4. The sensitivity of the anhydrous chloroform and anhydrous tetrachloroethylene was not great enough to cover the entire biologically interesting dose range.

5. A relative figure for the fast and thermal neutron sensitivity of these systems needed documentation by several investigations.

Utilizing the above-mentioned limitations of the chemical dosimetry systems as the objective for future research, cooperative experimentation continued. At Operation Redwing, it was determined that the fast neutron sensitivity of the anhydrous tetrachloroethylene system was not affected when the system was overlayered with a water-dye solution. Studies at Godiva, Omega, and Jezebel at Los Alamos Scientific Laboratory (LASL) and at Oak Ridge National Laboratory (ORNL) demonstrated the worth of the tin, aluminum, and lithium cans developed by Hurst and co-workers as a field shielding system. Further, a value for the fast and thermal neutron sensitivity of the gamma systems was established through cooperative ventures with Harris and his associates at Los Alamos.

Also, an objective method of evaluating the chemical dosimeters was developed through the procurement and modification of a Beckman model DK-2 ratio-recording spectrophotometer. Production problems were solved so that during the period from July to December 1956, 50,000 glass ampuls were cleaned and siliconed and 12,000 chemical dosimeters, of the specifications shown in table I, were prepared for Operation Plumbbob.

Most of these dosimeters were satisfactorily utilized in cooperative studies with CETG and Director, Weapons Effects Test (DWET). The data collected are contained in this report.

DOSIMETER SYSTEMS

Trichloroethylene 1-Phase Dosimeter

The 1-phase, water-equivalent dosimeter (1) was prepared by

TABLE I

<u>Range and numbers produced of Plumbbob chemical dosimeters</u>

Dose range	Color code	Number produced	pH range	Composition
100 mr - 1.0 r	White	100	5.8-5.4	0.1% ALC TCE no buffer
500 mr - 3.0 r	Black	300	5.9-5.2	1.0% ALC TCE no buffer
10 r - 200.0 r	Silver	2,600	660-5.0	0.2% IONOL* TCE no buffer
100 r - 500.0 r	Green	2,000	6.0-5.0	0.2% IONOL TCE .1% buffer
400 r - 1,600.0 r	Red	2,000	6.0-5.0	0.2% IONOL TCE 0.5% buffer
1,000 r - 5,000.0 r	Yellow	2,000	6.0-5.0	0.2% IONOL TCE 1.0% buffer
2,000 r - 20,000.0 r	Blue	2,000	6.0-5.0	0.2% IONOL TCE 5.0% buffer
1,000 r - 1,000.0 r	White	1,000	6.0-5.0	H_2O trichloroethylene no buffer

ALC - Ethyl alcohol.
TCE - Trichloroethylene.
*Registered name.

saturating triply distilled, low-conductivity water with a reagent-grade halogenated hydrocarbon such as trichloroethylene. A reagent-grade acidimetric dye was then added, and the solution was standardized to a given pH and color. This system shows a linear relationship between radiation dose and the acids liberated by the halogenated hydrocarbon. The acids liberated can be measured by back-titrating with a standard base solution or by spectrophotometric analysis.

This water-equivalent system, when housed in thin-walled glass containers of either Neutraglas or Pyrex, is energy independent from 50 kev to 12 mev. It is also dose-rate independent in ranges from a few milliroentgens per hour to the rates encountered in bomb tests. It is temperature independent ($\pm$ 5 percent) between 5° and 55° C. It has a definite neutron response; however, it produces only 0.5 as much acid per rep of fast neutrons as it does per roentgen of photons.

Tetrachloroethylene 2-Phase Dosimeter

Tetrachloroethylene, like chloroform, responds to x- and gamma radiation, producing water-soluble acids. Since the solubility of water in tetrachloroethylene is less than 0.01 percent, tetrachloroethylene can be exposed while overlayered with an acidimetric dye without its neutron sensitivity being affected (neutron sensitivity appears to be proportional to water solubility in the halogenated hydrocarbon). By use of this dosimeter (2) rather than a chloroform system, the problem of hydrocarbon volatility is overcome and the radiation sensitivity can be adjusted by simple chemical procedures.

The energy dependence of the tetrachloroethylene dosimeter somewhat parallels that of film. Peak response, as measured by acid production, is directly related to photoelectric absorption. Energy dependence is decreased above 0.6 mev as Compton scattering becomes more important.

IONOL-stabilized tetrachloroethylene is rate independent from 0.5 r/hr. to the rates encountered during nuclear detonations. Studies at the Radiobiological Laboratory[1] have varied the dose rate from 0.5 r/hr. to 4,200 r/min. These dosimeters are also relatively temperature independent (± 5 percent) during irradiation in the range of 5° to 55° C., and show a linear relation between radiation dose and the total acids liberated by the halogenated hydrocarbon. Acid production is linear up to doses greater than 200,000 r, regardless of rate.

Calibration of the 2-phase, tetrachloroethylene system indicated that its sensitivity to fast neutrons is less than 2 percent of its response to gamma rays.

In addition, Hurst calculated the energy absorbed per gram of tetrachloroethylene from 1 rep of fast neutrons for comparison with the energy absorbed per gram of tissue from 1 r of gamma radiation. The calculations for the tetrachloroethylene system indicated that a maximum of 8.3 percent of the incident

[1] Radiobiological Laboratory of the University of Texas and the United States Air Force, Austin, Texas.

energy of 8 mev neutrons is absorbed by the system when compared with the tissue dose. Since only 10 percent of the absorbed dose is utilized owing to the chemical efficiency of conversion for large particles, the neutron response of the tetrachloroethylene system, depending on the neutron spectrum, is of the order of 0.83 percent or less. That is, if exposed to 1 rep of fast neutrons with no gamma rays present, the dosimeter would generate 0.83 percent as much acid as it would for 1 r of gamma radiation.

NEUTRON AND GAMMA CALIBRATION

The 1-phase water-equivalent dosimeter and the 2-phase tetrachloroethylene dosimeters have been adequately cross-calibrated against the technics of Harris, Hurst, and Sayeg. These systems have been used with the fission-foil technic at the Nevada Test Site, Pacific Proving Grounds, Tower Shielding Facility, Godiva Assembly, LASL — Cockroft-Walton, ORNL 86-inch cyclotron, Argonne National Laboratory (ANL) 60-inch cyclotron and the ANL Research Reactor CP-5. Depending on the evaluation technic employed, reproducibility and accuracy within ± 5 percent have been obtained.

The final calibration of these systems was accomplished by a joint experiment conducted at the LASL Critical Assembly Godiva. In this experiment, ORNL supplied neutron dosimetry with the fission-foil technic. LASL supplied sulfur monitors for determining the number of fissions and Teflon carbon chambers for measuring coexistent gamma. Chemical dosimetry was used for differential neutron-gamma measurements as a function of distance from the center of Godiva.

The neutron rep measurements obtained with the 1-phase dosimeter were in good agreement with the total rep measurements obtained with the fission foils. Gamma measurements in the presence of neutrons agree well with theory and with the Teflon-carbon chamber when it was corrected for columnar recombination. (See figure 1 for representative data.)

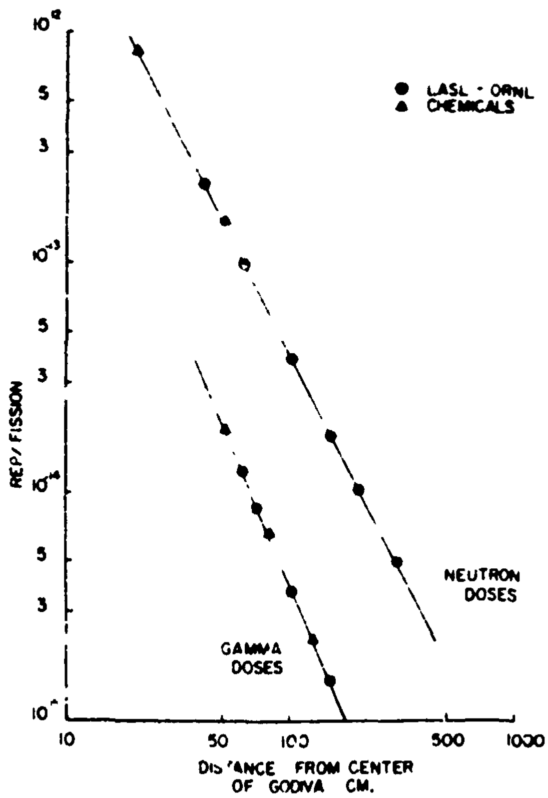

FIGURE 1

Comparative calibration of Godiva.

EVALUATION TECHNICS

General

Field evaluation of the two dosimetric systems used could have been accomplished by any of three methods: visual comparison, titration, or spectrophotometric evaluation. The spectrophotometric technic was chosen because it offered the greatest accuracy and the least chance for human error. In addition, the ampuls do not have to be opened as they do in the titration method and, thus, they can be kept for a permanent record.

Spectrophotometric Measurements of pH Changes in Solutions of Chlorphenol Red Indicator

Chlorphenol red, as used in the differential hydrogen-content system, has two absorption peaks at 580 and 432 mμ. As the pH of the dye solution is reduced from 6.4 to 5.0 (red to yellow), the percentage transmission at 580 and 432 mμ (percent T at 500 mμ and 430 msec.) change in an inverse relation (figure 2). In determining pH with a spectrophotometer, the mass-action law is applicable to acid and alkaline forms of an indicator dye in relation to pH as shown by the equation:

$$\frac{(H^+)\ (I^-)}{HI} = K$$

where HI is the relative acid form of the dye and I^- is the relative alkaline form. Therefore:

$$pH = \frac{\text{Log}\ (I^-)}{HI} + K$$

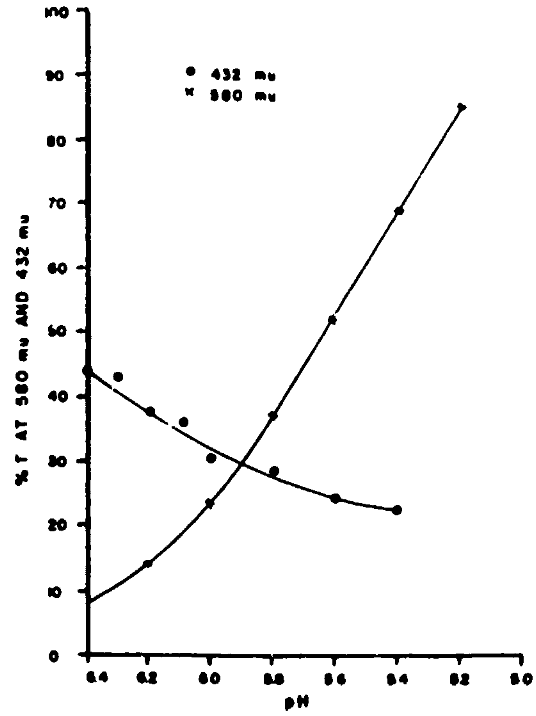

FIGURE 2

Percent transmission at 580 and 432 mμ vs. pH.

From the equations, it is apparent that pH is a function of the ratio of the acid over the alkaline forms of the dye, and conversely, pH controls the amounts of the two forms of the dye present only when the effects of temperature, buffering action, and impurities are controlled (figure 3).

Spectrophotometric Determination of Exposure Dosage

Using a Beckman model DK-2 ratio-recording spectrophotometer with suitable adapters, it is possible to evaluate the above-mentioned ratio changes (figures 4, 5, and 6).

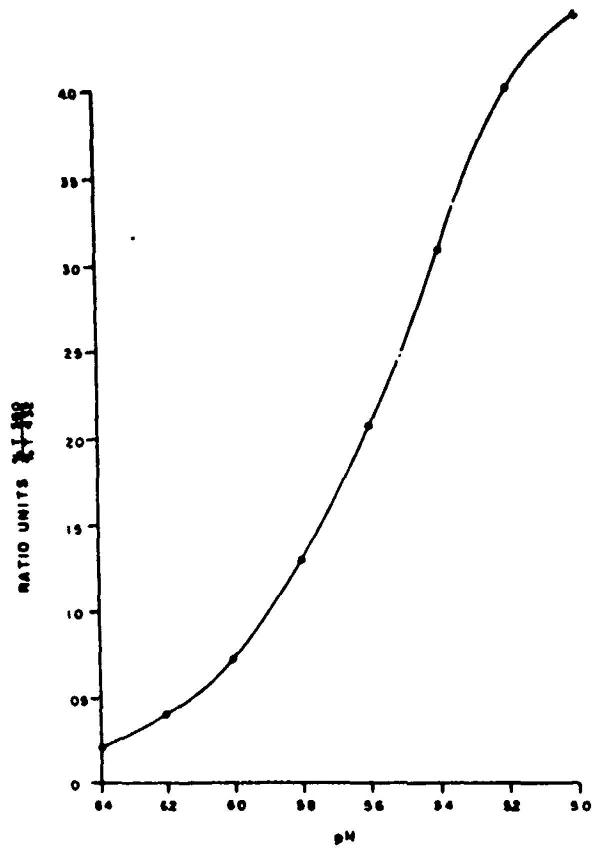

FIGURE 3

Ratio percent T 580 mμ percent T 432 mμ vs. pH.

Before exposure, the dosimeters are evaluated for their pre-exposure ratio (percent T 580 mμ / percent T 432 mμ). Dosimeters are then given known doses of radiation and are spectrophotometrically evaluated for their postexposure ratio. A curve of delta ratio units (postexposure ratio minus pre-exposure ratio) vs. dose is drawn. (See figure 7 showing

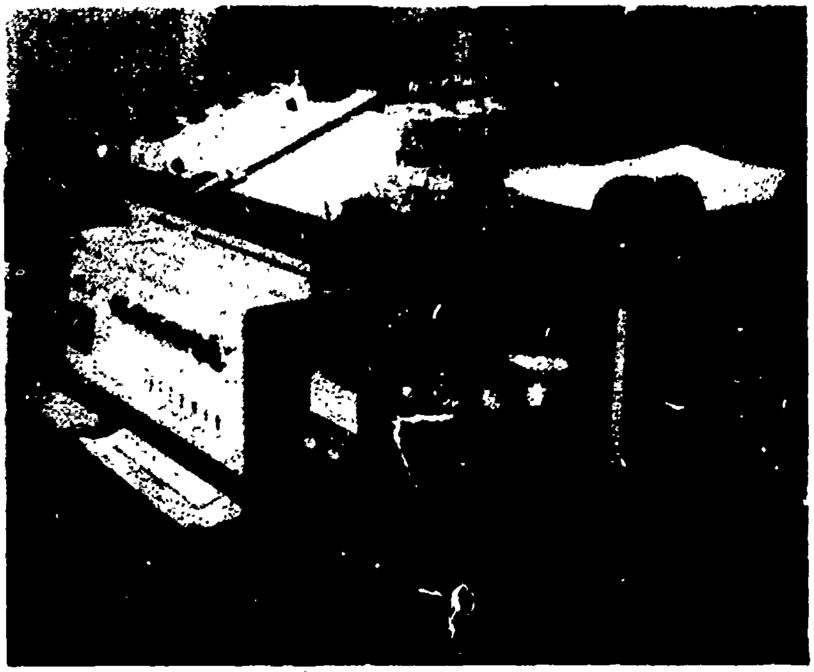

FIGURE 4

Beckman model DK-2 spectrophotometer, side view.

typical curve.) Once this curve is drawn for a specific dosimeter series, one can convert delta-ratio-units directly to dosage.

FIELD CONTAINER SYSTEMS

ORNL Lithium Can and Blast Shield

The thermal-neutron sensitivity of both chemical systems

FIGURE 5

Beckman model DK-2 spectrophotometer, front view.

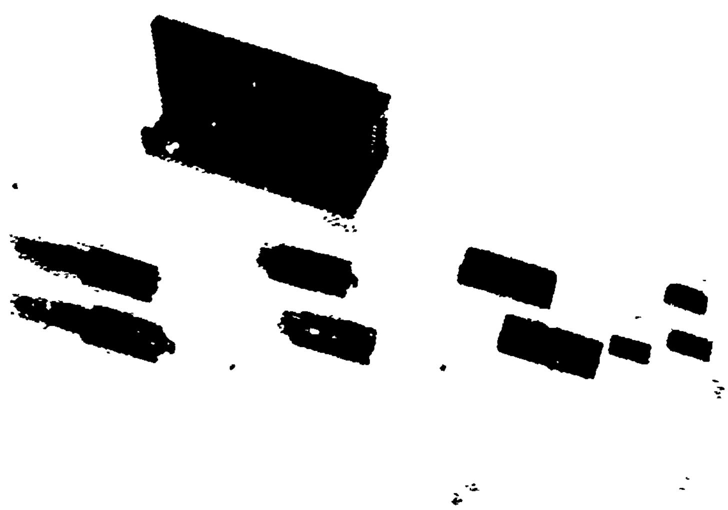

FIGURE 6

Adaptations for cuvette holder of Beckman model DK-2 spectrophotometer.

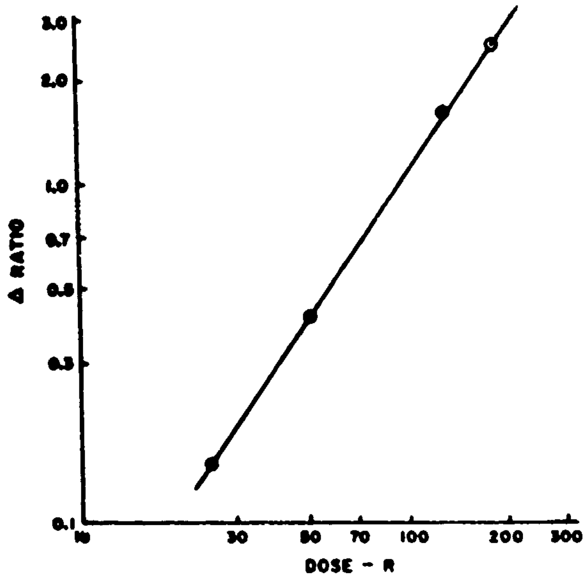

FIGURE 7

Delta percent T 580 mμ/Δpercent T 432 mu vs. dose for typical dosimeter.

FIGURE 8

Lithium can and blast shield assembly.

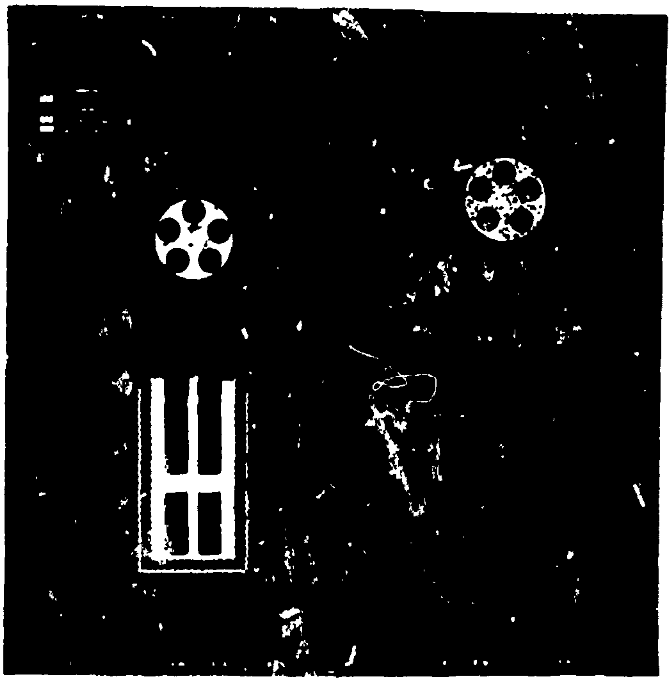

FIGURE 9

ORNL lithium can.

is high because of the 32-barn cross-section of chlorine. If no gamma rays are present, then 3.25×10^{13} thermal neutrons generate as much acid as 17 r of gamma rays in the 2-phase, tetrachloroethylene system. Therefore, when exposure to a high thermal-neutron flux is probable, adequate shielding is required. A recent development is the ORNL-designed can. (See figures 8 and 9.) This device was used with the chemical systems during Plumbbob.

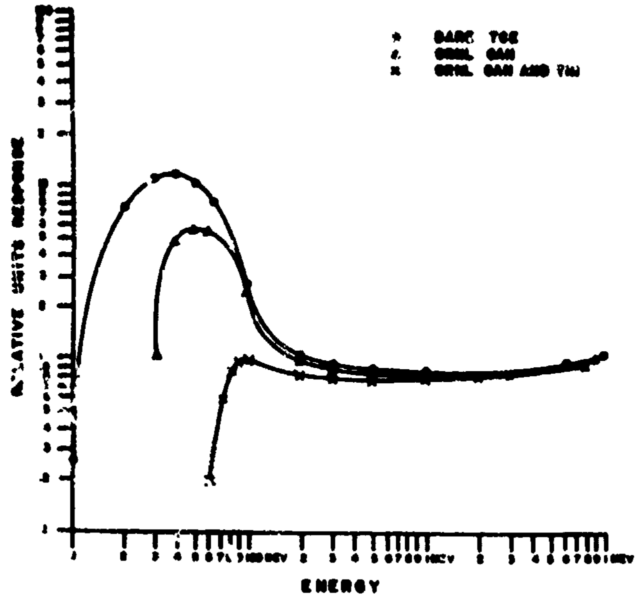

FIGURE 10

The effect of the ORNL lithium can with tin on energy dependence of tetrachloroethylene.

In addition to absorbing the thermalized neutrons, this containers system corrects for the energy dependence of the 2-phase tetrachloroethylene dosimeters so that one obtains relative energy independence for energies from 67 kev to 10 mev. (See figure 10 for energy response inside containers system.)

Each lithium can contains 0.6 lb. of lithium metal. Consequently, adequate provision must be made to protect the can against severe shock as well as flying missiles. This is afforded by a 1/4-in. thick cylindric shield. (See figure 8.)

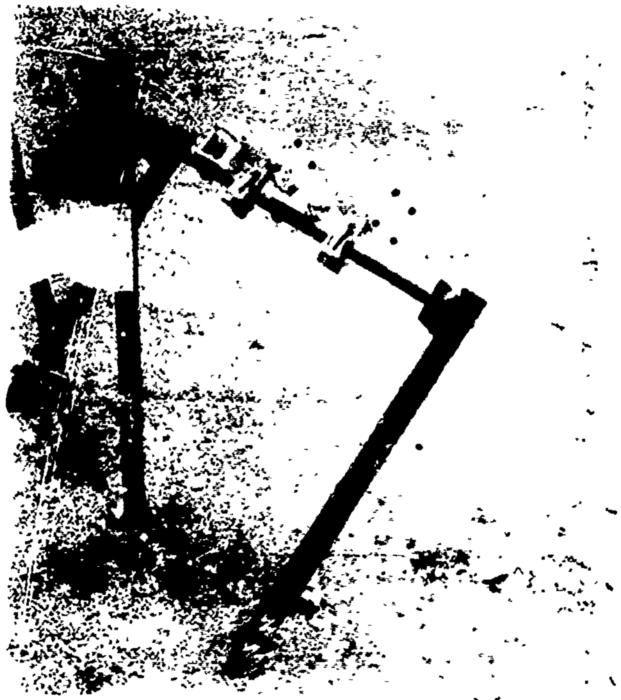

FIGURE 11

Shield goal-post installation.

OPERATIONS

Gamma Measurements

Ten thousand fast neutron insensitive gamma-ray chemical dosimeters plus 1,000 single-phase, water-equivalent dosimeters were made available to Civil Effects Test Group and Field Command Weapon Tests (Department of Defense) projects. Dosimeter evaluation was accomplished at the Nevada Test Site. Placement and recovery operations were performed by CETG and Department of Defense personnel. (See figures 11 and 12 for the type of equipment used to position dosimetry systems.)

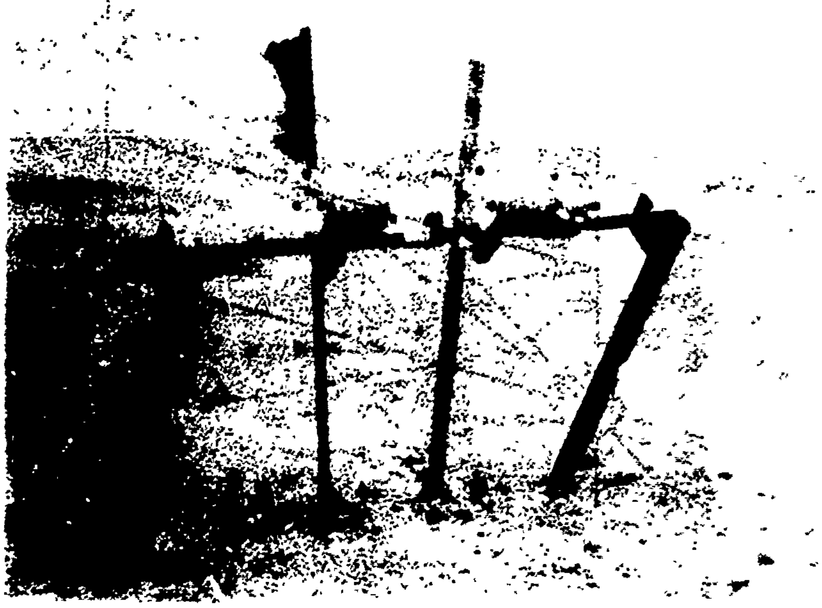

FIGURE 12

Shield goal-post installation.

Gamma Angular Distribution

Gamma collimators were placed by CETG Project 39. 5 (6) at various distances from ground zero on shots Franklin, Wilson, Hood, Stokes, Doppler, Franklin Prime, and Fizeau. Various specific azimuthal and elevation angles were investigated on each shot. Figure 13 defines the angular nomenclature for the collimator data presented in the appendix. The gamma collimators employed a water-tank unit

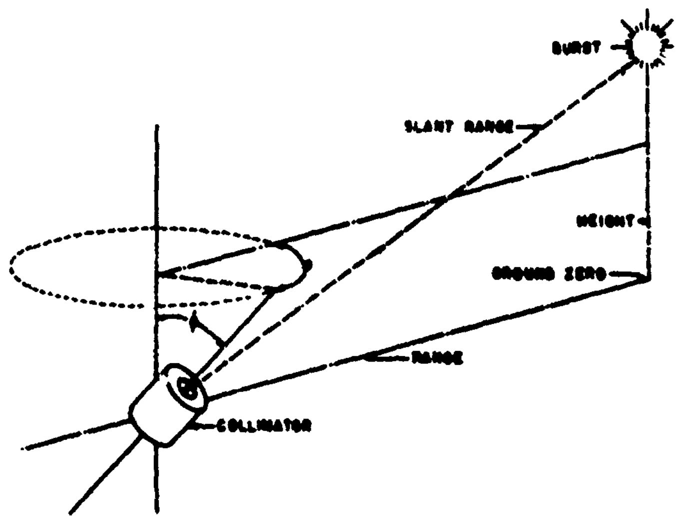

FIGURE 13

Nomenclature for angular measurements with the collimator.

which was basic to both neutron and gamma measurements. Into this basic unit lead inserts were placed for gamma collimation measurements. The lead inserts were made in more than one angular opening. The water-tank was necessary for the gamma collimators in order to prevent the fast neutrons from reaching the lead and producing gamma rays by inelastic scattering, which would lead to spurious results. (See figure 14.)

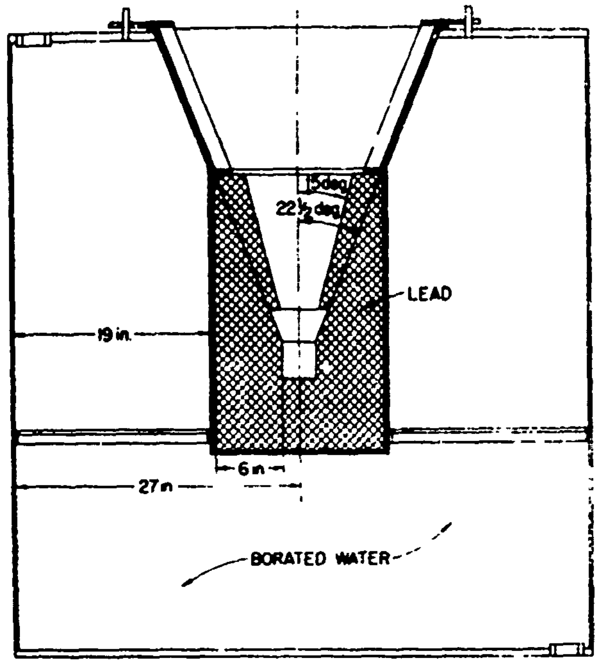

FIGURE 14

Gamma collimators with lead inserts.

RESULTS AND CONCLUSIONS

Results

The gamma measurements obtained with the USAF chemical dosimeters at various locations are presented in the appendix. All RD^2 vs. D (dose times slant distance^2 vs. slant distance) data has been analyzed by a method of "least squares" analysis. From this analysis, the slopes (relaxation lengths) of the radiation for the thirteen devices have been calculated and the radiation at zero distance per kT (R_0) has been determined.

Fair agreement for the R_o's calculated from the slopes by the least squares analysis method is found from device to device. It should be pointed out, however, that slight changes in the slope will produce enormous changes in the R_o's. Large variations in slope will be produced even when radiation measurements are within statistically valid ranges. A most interesting point, however, is that for Franklin, Wilson, Priscilla, Hood, and Stokes we find an R_o value equal to approximately 6.00×10^9 r/KT. The radiation measurements for determining these R_o values were all made in a region known to be free from extraneous material in the region of the cab and the device. It is suggested that part of the variability in the R_o's measured for the other device may be due in part to extra material placed around the device or in the cab.

The value 6.00×10^9 r/KT for the R_o in an "open-pie" situation is somewhat higher than those previously measured (4). This suggests a requirement for further measurements of the gamma radiation versus distance on several devices to be used in later test explosions. These measurements, of course, must be made in a region relatively free of extraneous material around the active material of the device.

Conclusions and Recommendations

The broad initial objectives of this project were met. Radiation measurements were supplied to the Department of Defense and Civil Effects Test Groups by the School of Aviation Medicine, USAF.

Although the operation was highly successful, points requiring improvements and further investigation were obvious at the end of the test. The read-out system, using the modified Beckman DK-2 spectrophotometer, was satisfactory; however, its operation was a tedious task on a mass scale, and dosimetry read-outs were too dependent on physical placement and internal adjustments of the DK-2. The operating time of the DK-2 spectrophotometer, required to produce an answer, is too long for a field system. Hence, it was decided that an instrument specifically adapted to dosimetric read-out should be designed for subsequent field tests. The following methods of evaluation have been proposed but will require considerable research before an adequate field dosimetric reader can be designed:

1. A DK-2 spectrophotometric system with an automatic height- and area-positioning mechanisms.

2. A spectrophotometric system utilizing two narrow-band filters with appropriate electronics for rationing the two spectrophotometric peaks along with a digital read-out mechanism.

3. A one filter system utilizing automatic positioning and a mechanism for a digital read-out.

4. A system that will measure the solution power or dissipation factor for dosimetric evaluation.

5. A system utilizing the change of the dielectric constant of the solutions as a means of dosimetric evaluation.

6. A system measuring the change in "Q" of the dosimetric solution as a means of evaluation.

7. A system for measuring the insertion loss for the dosimetric solution as a method of evaluation.

8. A system utilizing low frequency (electrode) conductivity as a method of evaluation.

9. A system utilizing high frequency (electrodeless) conductivity as a means of evaluation.

10. A system using a fluorometric evaluation as a dosimetric indicator system.

11. A system using the nuclear magnetic resonance of free radicals as an indicator system.

12. A system utilizing the electron paramagnetic resonance of free radicals as an indicator system.

In addition to an improved field read-out mechanism, other areas of investigation for improving the halogenated dosimetric technics were indicated by this field test:

1. A more radiation-resistant glass is needed or possibly a radiation-resistant plastic can be substitued for the capsulation of the dosimetric solutions.

2. Machine (automatic) filling and sealing are a requirement for the large-scale production of the chemical dosimeters.

3. Alkali liberation at the seal point needs to be limited or eliminated. Plastic-to-plastic radio frequency sealing is one consideration and a second consideration would be a plastic pressure plug or cap system.

4. In the production of chemical dosimetric systems, the preparation of ampuls is tedious and exacting; methods should be developed to make this phase of the work less difficult.

5. Tho acid extraction time of the present system proved to be rather long during the present operation (requiring a minimum of 12 hours postirradiation). One possible solution to shorten the extraction time would be the use of an ultransonic emulsifier followed by centrigugation prior to read-out.

6. New dye-water hydrocarbon systems should be considered that will cover a larger dose range to eliminate the present overlap system. At the upper range of one system and the lower range of a second system, correlation of the read-out between two types of dosimeters for the same dose is often unsatisfactory.

Further, on the theoretic level, areas of research on the halogenated hydrocarbon system should be directed to the following studies:

1. A better understanding of the radiation chemistry involved for these sytems.

2. Establishment of the G value for alpha particles of different energy, protons, and carbon recoil atoms, as a function of dissolved gas composition.

To prepare for the field operations in CETG and DWET studies for Operation Plumbbob, three man-years expended over a five-month period were required. If field work utilizing these systems is to be considered in the future, at the same level as this operation or at a greater magnitude, it is imperative that the ideas for research and development, suggested above, be attacked in the near future.

In a project of this magnitude, many organizations and individuals must of necessity be involved. The authors are indebted to many of the members of the following organizations, who, under arduous circumstances and at odd hours, made the operation a success: Physics and Engineering Group, Radiobiological Laboratory, USAF, and the University of Texas, Austin, Texas:; Department of Radiobiology, School of Aviation Medicine, USAF, Randolph Air Force Base, Texas; Project 39.5, ORNL; Project 39.6, SAM; and Project 39.7, LASL - H-4.

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APPENDIX A

GAMMA MEASUREMENTS

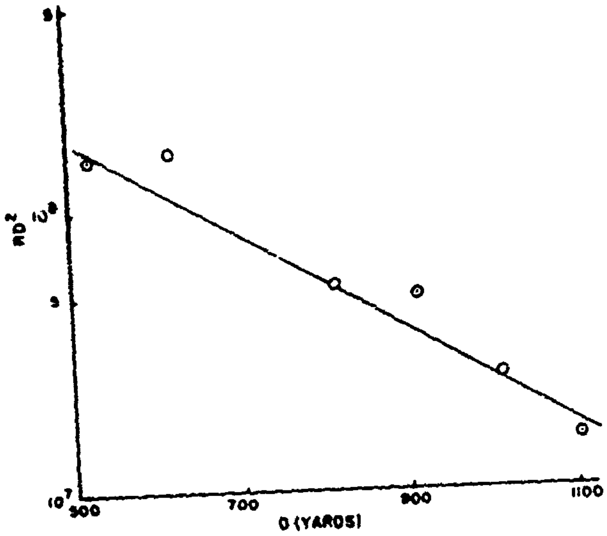

FIGURE A-1

Franklin initial gamma radiation, north line, $342^{\circ}19'56''$.

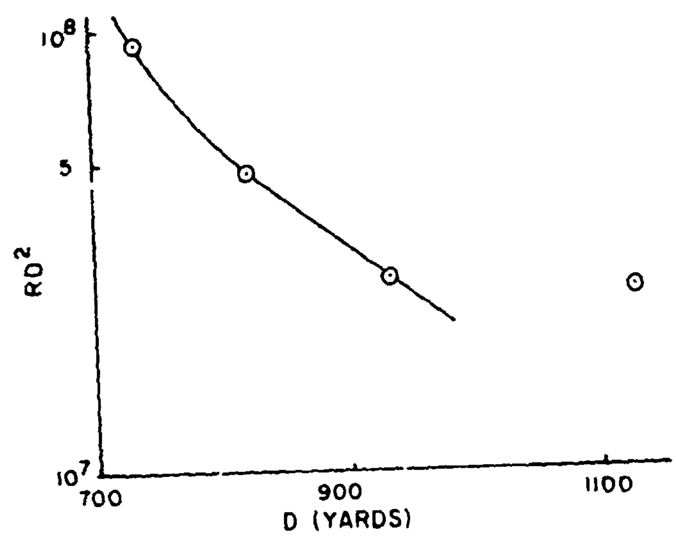

FIGURE A-2

Franklin initial gamma radiation, south line, $\cong 195^{\circ}$.

TABLE A-1

Goal-post data, Franklin

(Area 3, 300-ft. tower, north line, 342°19'56" Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
500	510	2.6×10^5	540	1.4×10^8
600	609	3.71×10^5	400	1.48×10^8
700	Broken			
800	806	6.50×10^5	80	5.20×10^7
900	905	8.19×10^5	58	4.75×10^7
1,000	1,004	1.01×10^6	25	2.53×10^7
1,100	1,104	1.22×10^6	12	1.46×10^7
1,200	Broken			

TABLE A-2

Goal-post data, Franklin

(Area 3, 300-ft. tower, south line, $\cong$195° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
720	727	5.28×10^5	178	9.40×10^7
810	816	6.66×10^5	70	4.66×10^7
925	930	8.66×10^5	31	2.68×10^7
1,125	1,127	1.27×10^6	20	2.54×10^7

TABLE A-3

Collimator data, Franklin, 500 yards

(Area 3, 300-ft. tower, north line, 342°19'56" Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (φ) (deg.)	Attenuator thickness	Dose (r)
51	30° Pb*	0	67.5	None	260
52	45° None	0	67.5	None	260
53	45° None	0	90.0	None	260
54	45° None	0	22.5	None	280
55	45° None	45	67.5	None	< 20
56	45° None	180	22.5	None	< 20
57	45° None	180	67.5	None	< 20
58	45° None	135	67.5	None	< 20
59	45° None	90	40.0	None	44
60	45° None	90	67.5	None	< 20

*Lead.

TABLE A-4

Collimator data, Franklin, 750 yards

(Area 3, 300-ft. tower, north line, 342°19'56" Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (φ) (deg.)	Attenuator thickness	Dose (r)
31	30° Pb	0	67.5	None	<20
32	45° None	0	67.5	None	<20
33	45° None	0	90.0	None	40
34	45° None	0	22.5	None	40
35	45° None	45	67.5	None	0
36	45° None	180	22.5	None	<20
37	45° None	180	67.5	None	<20
38	45° None	135	67.5	None	<20
39	45° None	90	40.0	None	<20
40	45° None	90	67.5	None	<20

TABLE A-5

Support instrumentation, Franklin

Project	Agency	Description	Number of dosimeters supplied
39.7	CETG	Rerun of gamma distribution in Greenhouse mouse-exposure container	150
39.7	CETG	In vivo depth-dose (pig)	60
39.8	CETG	Phantom depth-dose	500
1.1	METG*	M-48 tank neutron-gamma attenuation	75
2.3	METG	Ontos vehicle neutron-gamma attenuation	25

* Military Effects Test Group.

TABLE A-6

Goal-post data, Wilson

(Area 9a, 500-ft. balloon, 120° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
500	525	2.76×10^5	36,600	1.01×10^{10}
625	645	4.16×10^5	17,900	7.45×10^9
750	765	5.85×10^5	9,450	5.53×10^9
1,000	1,015	1.03×10^6	2,750	2.83×10^9
1,250	1,250	1.56×10^6	800	1.43×10^9
1,500	1,500	2.25×10^6	275	7.1×10^8
1,750	1,750	3.06×10^6	117	3.6×10^8
2,000	2,000	4.0×10^6	45	1.8×10^8

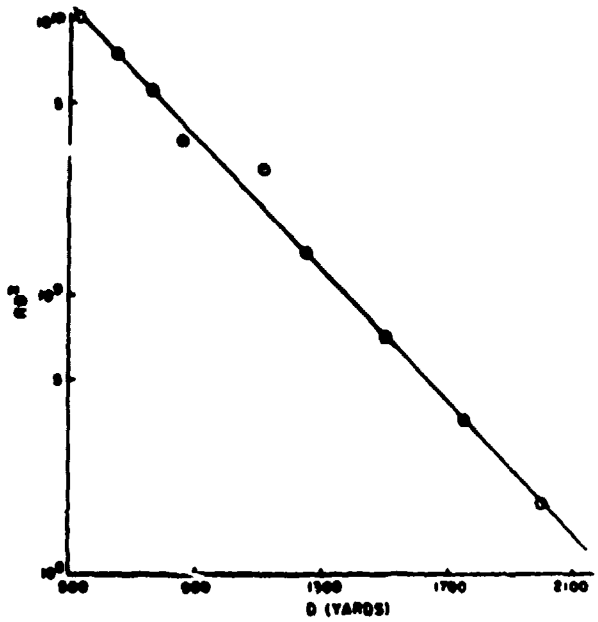

FIGURE A-3

Wilson initial gamma radiation, east line, 120°.

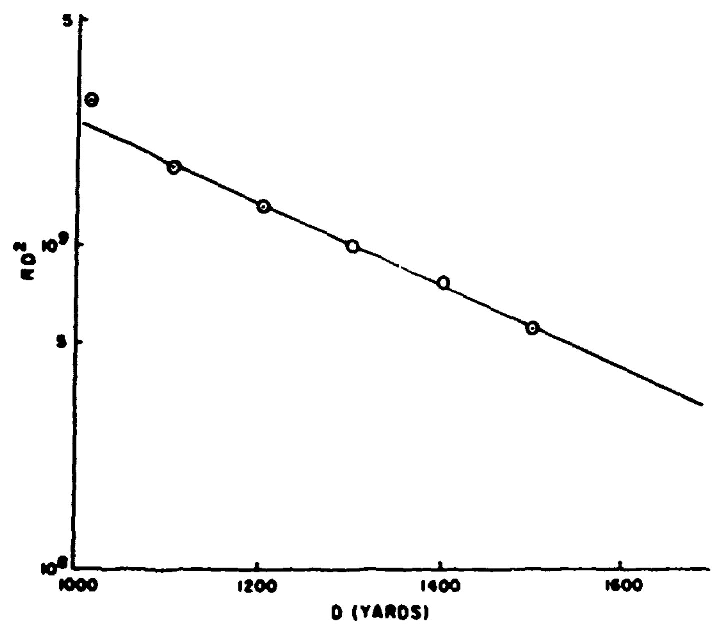

FIGURE A-4

Wilson initial gamma radiation, south line, 204°.

TABLE A-7

Goal-post data, Wilson

(Area 9a, 500-ft. balloon, 204° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
1,000	1,015	1.03×10^6	2,750	2.83×10^9
1,100	1,105	1.22×10^6	1,450	1.77×10^9
1,200	1,200	1.44×10^6	930	1.34×10^9
1,300	1,300	1.69×10^6	600	1.01×10^9
1,400	1,400	1.96×10^6	400	7.84×10^8
1,500	1,500	2.25×10^6	250	5.63×10^8

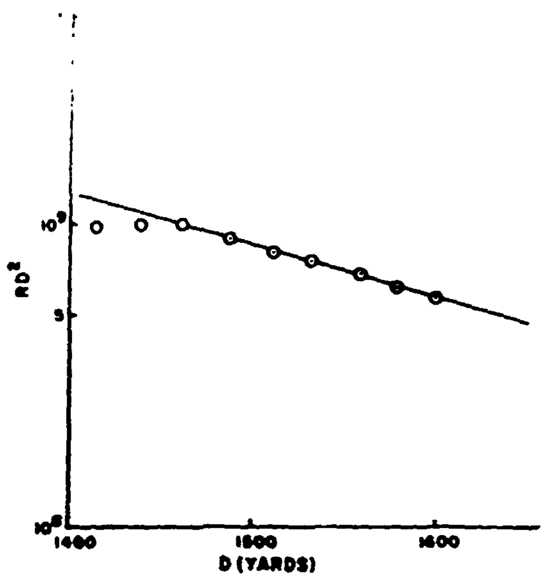

FIGURE A-5

Wilson initial gamma radiation, monkey line, 120°.

TABLE A-8

Monkey gamma exposure line

(Area 9a, 500-ft. balloon, 120° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
1,325	1,414	2.00×10^6	481	9.62×10^8
1,350	1,438	2.07×10^6	475	9.83×10^8
1,375	1,462	2.14×10^6	455	9.74×10^8
1,400	1,488	2.21×10^6	395	8.73×10^8
1,425	1,512	2.28×10^6	347	7.91×10^8
1,450	1,533	2.35×10^6	315	7.40×10^8
1,475	1,561	2.43×10^6	278	6.76×10^8
1,500	1,580	2.50×10^6	244	6.10×10^8
1,525	1,601	2.57×10^6	217	5.58×10^8

TABLE A-9

Collimator data, Wilson, 500 yards

(Area 9a, 500 ft. balloon, 120° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (ø) (deg.)	Attenuator thickness	Dose (r)
11	45° None	350	68	None	12,[illegible]00
12	45° None	10	40	None	4,100
13	45° None	24	70	None	11,000
14	45° None	23	62	None	Lost
15	45° None	251	68	None	Lost
16	45° None	320	24	None	4,500
17	45° None	292	64	None	1,650
18	45° None	220	24	None	2,000

TABLE A-10

Collimator data, Wilson, 750 yards

(Area 9a, 500-ft. balloon, 120° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
19	30° Pb	0	70	None	3500
20	30° Pb	356	45	None	850
21	30° Pb	30	77	None	700
22	30° Pb	25	57	None	880
23	30° Pb	330	77	None	1040
24	30° Pb	335	57	None	790
25	30° Pb	58	66	None	525
26	45° None	144	22	None	250
27	45° None	225	25	None	250
28	45° None	121	67	None	160
29	45° None	236	55	None	187
30	45° None	129	25	None	210
31	45° None	108	68	None	210
32	45° None	236	23	None	285

TABLE A-11

Collimator data, Wilson, 1,000 yards

(Area 9a, 500-ft. balloon, 120° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
33	30° Pb	0	75.0	None	940.0
34	30° Pb	0	50.0	None	255.0
35	30° Pb	30	80.0	None	205.0
36	30° Pb	330	80.0	None	200.0
37	30° Pb	25	60.0	None	405.0
38	30° Pb	335	60.0	None	310.0
39	45° None	70	67.0	None	94.0
40	45° None	221	22.5	None	60.0
41	45° None	132	23.0	None	80.0
42	45° None	241	76.0	None	46.0
43	45° None	120	68.0	None	42.5
44	45° None	114	23.0	None	58.0
45	45° None	232	25.0	None	60.0
46	45° None	104	29.0	None	57.0

TABLE A-12

Collimator data, Wilson, 1,250 yards

(Area 9a, 500-ft. balloon, 120° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
47	30° Pb	0	82	None	302.0
48	30° Pb	0	52	None	79.0
49	30° Pb	30	82	None	54.0
50	30° Pb	330	82	None	68.0
51	30° Pb	25	62	None	70.0
52	30° Pb	335	62	None	66.0
53	45° None	70	68	None	6.6
54	45° None	150	25	None	4.1
55	45° None	214	23	None	5.1
56	45° None	122	66	None	3.8
57	45° None	112	68	None	3.3
58	45° None	55	24	None	11.1
59	45° None	72	22	None	8.4
60	45° None	18	66	None	6.6

TABLE A-13

Collimator data, Wilson, 1,500 yards

(Area 9a, 500-ft. balloon, 120° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
61	45° None	18	84	None	86.0
62	45° None	0	54	None	42.2
63	45° None	30	84	None	18.0
64	45° None	330	82	None	15.0
65	45° None	25	63	None	37.5
66	45° None	335	63	None	10.5
67	45° None	73	65	None	3.7
68	45° None	75	65	None	1.6
69	45° None	40	15	None	3.9
70	45° None	296	23	None	2.75
71	45° None	120	69	None	1.8
72	45° None	240	68	None	1.0
73	45° None	162	20	None	1.55
74	45° None	218	21	None	1.4

TABLE A-14

Support instrumentation, Wilson

Project	Agency	Description	Number of dosimeters supplied
39.7	CETG	In vivo depth-dose (pig)	60
39.7	CETG	Rerun of gamma distribution in Greenhouse mouse-exposure container	150
39.8	CETG	Phantom depth-dose	500
2.4	METG	M-48 tank attenuation	75
2.10	METG	Air-phase propagation	120

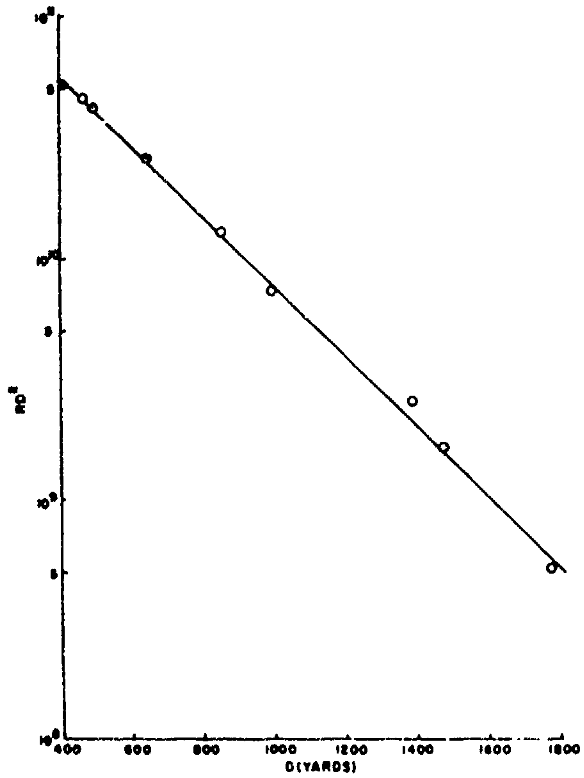

FIGURE A-6

Priscilla initial gamma radiation, 270°.

TABLE A-15

Goal-post data, Priscilla, gamma

(Frenchman Flat, 750-ft. balloon, 270° Az.)

Slant range (D) (yd.)	D^2	Dose (r)	RD^2
410	1.68×10^5	3.00×10^5	5.04×10^{10}
470	2.21×10^5	2.05×10^5	4.53×10^{10}
500	2.50×10^5	1.65×10^5	4.13×10^{10}
560	3.14×10^5	1.15×10^5	3.61×10^{10}
650	4.23×10^5	6.00×10^4	2.54×10^{10}
860	7.40×10^5	1.70×10^4	1.26×10^{10}
1,000	1.00×10^6	7,200	7.20×10^9
1,383	1.91×10^6	1,290	2.46×10^9
1,477	2.18×10^6	740	1.61×10^9
1,773	3.14×10^6	162	5.09×10^8

TABLE A-16

Support instrumentation, Priscilla

Project	Agency	Description	Number of dosimeters supplied
39.7	CETG	In vivo depth-dose (pig)	60
39.7	CETG	Goal-post line	75
30.2 30.3	CETG	Proj. 30 shelter studies	75
2.4	DOD*	Shelter studies	500

*Department of Defense.

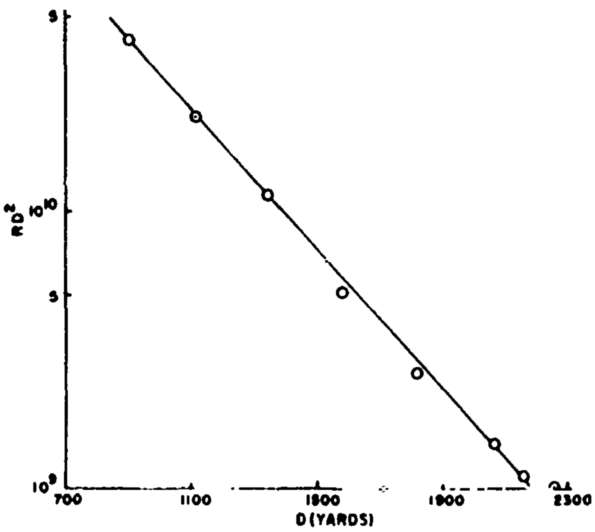

FIGURE A-7

Hood initial gamma radiation, 120°.

TABLE A-17

Goal-post data, Hood

(Area 9a, 1,500-ft. balloon, 120° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
		Flat land		
750	902	8.14×10^5	50,700	4.13×10^{10}
1,000	1,116	1.25×10^6	17,600	2.2×10^{10}
1,250	1,345	1.81×10^6	6,400	1.16×10^{10}
1,500	1,580	2.50×10^6	2,050	5.13×10^9
1,750	1,818	3.31×10^6	790	2.61×10^9
2,000	2,060	4.24×10^6	350	1.48×10^9
2,100	2,158	4.66×10^6	242	1.13×10^9
2,200	2,256	5.09×10^6	200	1.02×10^9
2,300	2,354	5.54×10^6	140	7.76×10^8
		Over hill*		
2,100	2,158	4.66×10^6	200	9.32×10^8
2,200	2,256	5.09×10^6	177	9.01×10^8
2,300	2,354	5.54×10^6	145	8.03×10^8

*Slant range is approximate.

TABLE A-18

Collimator data, Hood, 1,250 yards

(Area 9a, 1,500-ft. balloon, 120° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
11	30° Pb	1.25	67.0	None	1,860
12	30° Pb	4.0	66.5	3 in. sand	1,200
13	30° Pb	2.0	67.0	6 in. sand	900
14	20° Pb	4.5	67.0	None	1,660
15	30° Pb	8.0	37.0	None	600
16	30° Pb	2.0	8.0	None	115
17	30° Pb	23.0	84.0	None	370
18	30° Pb	29.0	54.0	None	420
19	30° Pb	3.0	94.0	None	435
20	30° Pb	0.0	105.0	None	100
21	30° Pb	29.0	101.0	None	100
22	30° Pb	54.0	90.0	None	85
23	30° Pb	66.0	61.0	None	109
24	30° Pb	46.0	33.0	None	135
25	45° None	110.0	71.0	None	120
26	45° None	110.0	71.0	3 in. sand	65
27	45° None	110.0	71.0	6 in. sand	78
28	45° None	110.0	71.0	None	95
29	45° None	135.0	30.0	None	97
30	45° None	157.0	69.0	None	80

TABLE A-19

Collimator data, Hood, 1,500 yards

(Area 9a, 1,500-ft. balloon, 120° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
31	30° Pb	3	72.0	None	815
32	30° Pb	2	70.5	3 in. sand	620
33	30° Pb	1	70.5	6 in. sand	317
34	20° Pb	1	69.0	None	590
35	30° Pb	3	10.0	None	205
36	30° Pb	2	12.0	None	34
37	30° Pb	27	85.0	None	125
38	30° Pb	31	57.0	None	157
39	30° Pb	4	98.0	None	105
40	30° Pb	7	120.0	None	32
41	30° Pb	30	112.0	None	70
42	30° Pb	51	98.0	None	78
43	30° Pb	64	64.0	None	37
44	30° Pb	34	54.0	None	83
45	45° None	104	70.0	None	26
46	45° None	135	29.0	None	35
47	45° None	161	69.0	None	25

TABLE A-20

Collimator data, Hood, 1,750 yards

(Area 9a, 1,500-ft. balloon, 120° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
48	30° Pb	2	73	None	322.0
49	30° Pb	0	72	None	205.0
50	30° Pb	1	73	None	175.0
51	30° Pb	4	43	None	65.0
52	30° Pb	2	14	None	33.0
53	30° Pb	26	89	None	45.0
54	30° Pb	26	61	None	61.0
55	30° Pb	2	103	None	53.0
56	30° Pb	4	134	None	Lost
57	30° Pb	35	107	None	15.0
58	45° None	54	98	None	22.0
59	45° None	63	69	None	24.0
60	45° None	42	38	None	33.0
61	45° None	109	71	None	3.0
62	45° None	136	30	None	6.4
63	45° None	156	18	None	4.3

TABLE A-21

Support instrumentation, Hood

Project	Agency	Description	Number of dosimeters supplied
2.10	METG	Air-phase propagation	120

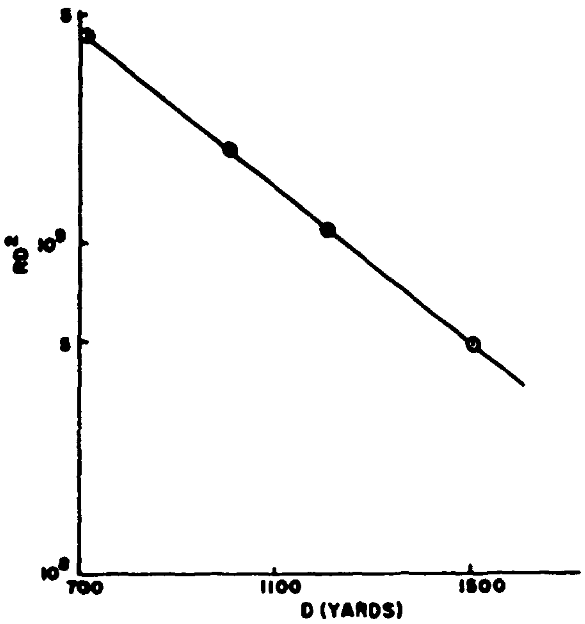

FIGURE A-8

Diablo initial gamma radiation, 90°.

TABLE A-22

Goal-post data, Diablo

(Area 2b, 500-ft. tower, 90° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
700	719	5.17×10^5	8,500	4.39×10^9
1,000	1,013	1.03×10^6	1,850	1.91×10^9
1,200	1,212	1.47×10^6	740	1.09×10^9
1,500	1,510	2.28×10^6	213	4.86×10^8

TABLE A-23

Support instrumentation, Diablo

Project	Agency	Description	Number of dosimeters supplied
2.10	METG	Air-phase propagation	90

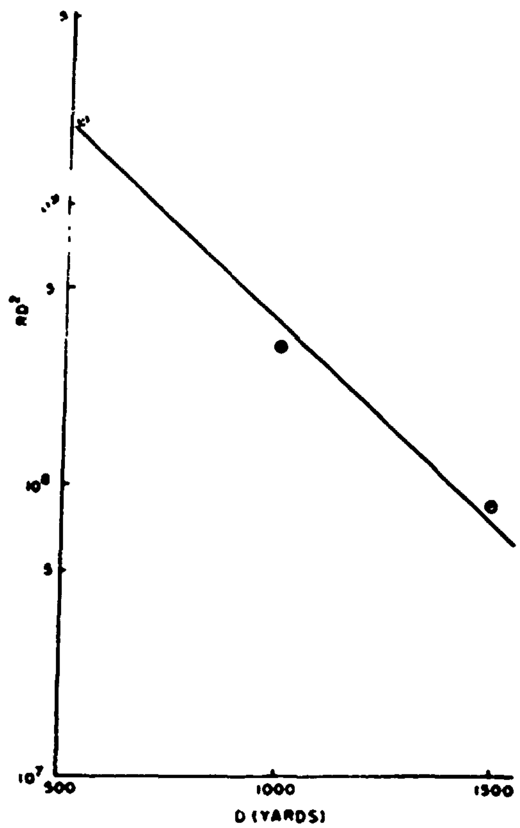

FIGURE A-9

Kepler initial gamma radiation, 90°.

TABLE A-24

Goal-post data, Kepler

(Area 4, 500-ft. tower, 90° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
500	527	2.78×10^5	7200	2.00×10^9
1,000	1,013	1.03×10^6	295	3.04×10^8
1,500	1,510	2.28×10^6	36	8.21×10^7

TABLE A-25

Support instrumentation, Kepler

Project	Agency	Description	Number of dosimeters supplied
30.1	CETG	Shelter instrumentation	50

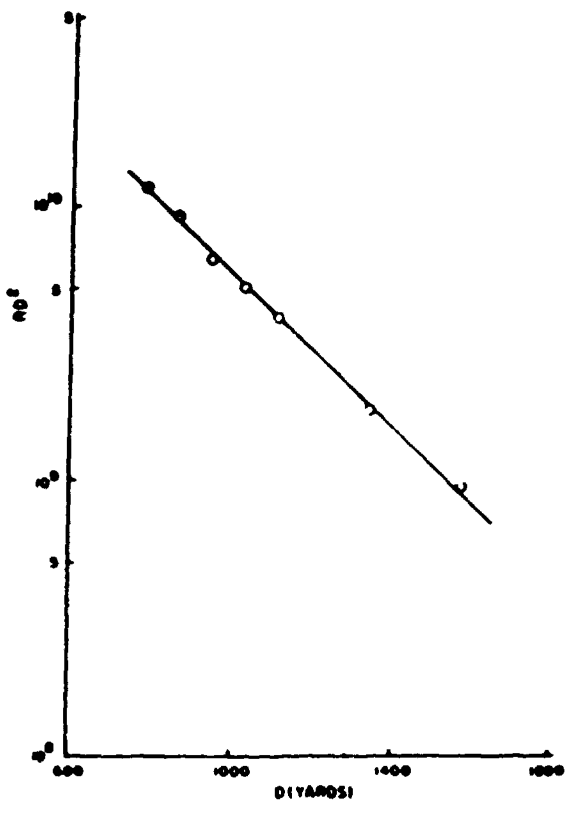

FIGURE A-10

Stokes initial gamma radiation, 160°.

TABLE A-26

Goal-post data, Stokes

(Area 7b, 1,500-ft. balloon, 160° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
600	782	6.12×10^5	19,300	1.18×10^{10}
700	861	7.41×10^5	12,500	9.26×10^9
800	944	8.91×10^5	7,350	6.55×10^9
900	1,030	1.06×10^6	4,900	5.19×10^9
1,000	1,116	1.25×10^6	3,200	4.00×10^9
1,250	1,345	1.81×10^6	1,025	1.86×10^9
1.500	1,580	2.50×10^6	390	9.76×10^8

TABLE A-27

Collimator data, Stokes, 750 yards

(Area 7b, 1,500-ft. balloon, 160° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
11	20° Pb	0	56	None	3,250
12	30° Pb	0	56	None	3,000
13	30° Pb	0	56	3 in. sand	1,900
14	30° Pb	0	56	6 in. sand	1,210
15	30° Pb	0	56	9 in. sand	900
16	45° None	0	56	None	4.100
17	30° Pb	0	19	None	580
18	30° Pb	45	40	None	610
19	30° Pb	39	70	None	510
20	30° Pb	39	70	3 in. sand	350
21	30° Pb	39	70	6 in. sand	230
22	30° Pb	39	70	9 in. sand	175
23	30° Pb	0	93	None	355
24	20° Pb	0	76	None	825
25	20° Pb	0	96	None	280
26	20° Pb	22	83	None	440
27	30° Pb	0	123	None	170
28	30° Pb	28	107	None	203
29	45° None	62	122	None	348
30	45° None	75	80	None	250
31	45° None	100	43	None	330
32	45° None	110	108	None	282
33	45° None	134	73	None	172
34	45° None	108	18	None	291
35	45° None	162	108	None	253
36	45° None	180	62	None	168

TABLE A-28

Collimator data, Stokes, 1,000 yards

(Area 7b, 1,500-ft. balloon, 160° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Φ) (deg.)	Attenuator thickness	Dose (r)
37	20° Pb	0	63	None	1,000.0
38	20° Pb	0	63	3 in. sand	650.0
39	20° Pb	0	63	6 in. sand	410.0
40	20° Pb	0	63	9 in. sand	275.0
41	30° Pb	0	63	None	1,010.0
42	45° None	0	63	None	1,420.0
43	30° Pb	0	26	None	155.0
44	30° Pb	40	42	None	136.0
45	30° Pb	40	70	None	122.0
46	30° Pb	25	92	None	74.0
47	30° Pb	0	100	None	94.0
48	45° None	117	18	None	90.0
49	45° None	84	57	None	76.0
50	45° None	243	90	None	66.0
51	45° None	30	129	None	64.0
52	45° None	160	109	None	66.0
53	45° None	94	126	None	67.0
54	30° Pb	154	64	None	35.0
55	30° Pb	154	64	3 in. sand	24.5
56	30° Pb	154	64	6 in. sand	20.0
57	30° Pb	154	64	9 in. sand	17.5
58	45° None	63	97	None	90.0

TABLE A-29

Collimator data, Stokes, 1,250 yards

(Area 7b, 1,500-ft. balloon, 160° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Φ) (deg.)	Attenuator thickness	Dose (r)
59	20° Pb	0	68	None	380.0
60	30° Pb	0	68	None	335.0
61	30° Pb	0	68	3 in. sand	215.0
62	30° Pb	0	68	6 in. sand	183.0
63	30° Pb	0	68	9 in. sand	155.0
64	45° None	0	68	None	>225.0
65	30° Pb	0	31	None	59.0
66	30° Pb	37	47	None	45.0
67	30° Pb	39	72	None	53.0
68	30° Pb	39	72	3 in. sand	39.0
69	30° Pb	39	72	6 in. sand	25.0
70	30° Pb	25	96	None	43.0
71	30° Pb	0	105	None	32.0
72	45° None	62	106	None	41.0
73	45° None	79	63	None	36.0
74	45° None	111	15	None	33.0
75	30° Pb	25	125	None	23.0
76	45° None	180	43	None	26.0
77	45° None	128	67	None	27.5
78	45° None	180	85	None	17.5
79	45° None	147	114	None	35.0
80	45° None	107	106	None	21.5

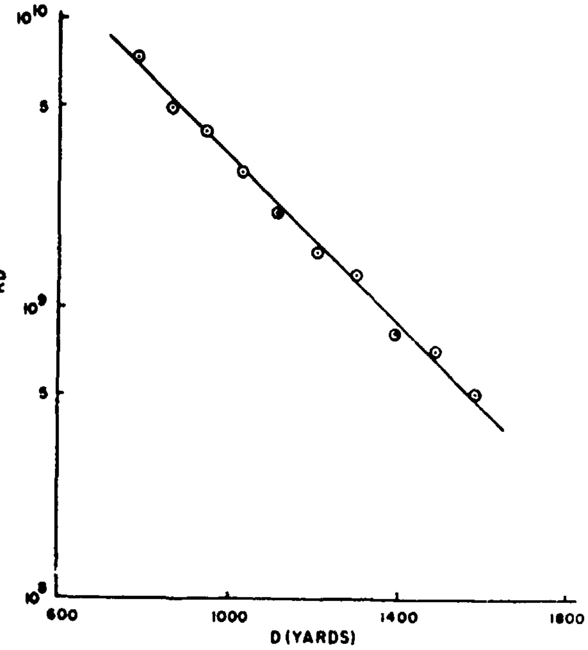

FIGURE A-11

Doppler initial gamma radiation, 160^0.

TABLE A-30

Goal-post data, Doppler

(Area 7b, 1,500-ft. balloon, 160° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
600	782	6.12×10^5	11,900	7.28×10^9
700	861	7.41×10^5	6,650	4.93×10^9
800	944	8.91×10^5	4,620	4.12×10^9
900	1,030	1.06×10^6	2,790	2.96×10^9
1,000	1,116	1.25×10^6	1,700	2.13×10^9
1,100	1,208	1.46×10^6	1,075	1.57×10^9
1,200	1,300	1.69×10^6	770	1.30×10^9
1,300	1,392	1.94×10^6	420	8.15×10^8
1,400	1,486	2.21×10^6	324	7.16×10^8
1,500	1,580	2.50×10^6	203	5.08×10^8

TABLE A-31

Collimator data, Doppler, 750 yards

(Area 7b, 1,500-ft. balloon, 160° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
11	20° Pb	0	56.0	None	1,565.0
12	20° Pb	0	56.0	6 in. sand	640.0
13	45° None	0	56.0	None	2,170.0
14	45° None	0	56.0	6 in. sand	890.0
15	30° Pb	0	90.0	None	266.0
16	30° Pb	2	91.0	6 in. sand	131.0
17	30° Pb	20	72.0	None	420.0
18	30° Pb	22	72.0	6 in. sand	168.0
19	30° Pb	44	72.0	None	142.0
20	30° Pb	42	72.0	6 in. sand	113.0
21	45° None	67	72.0	None	216.0
22	45° None	67	71.5	6 in. sand	145.0
23	30° Pb	68	71.5	None	100.0
24	30° Pb	69	71.5	6 in. sand	64.0
25	45° None	98	73.0	None	295.0
26	45° None	100	69.0	6 in. sand	90.0
27	45° None	130	69.0	None	125.0
28	45° None	130	70.0	6 in. sand	93.0
29	45° None	163	71.0	None	87.0
30	45° None	160	68.0	6 in. sand	61.0
x	30° Pb	0	180.0	None	12.5
y	20° Pb	180	71.5	None	98.0
z	30° Pb	180	71.5	None	92.0

TABLE A-32

Collimator data, Doppler, 1,000 yards

(Area 7b, 1,500-ft. balloon, 160° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
37	30° Pb	0	63.5	None	660
38	45° None	0	63.5	None	835
39	30° Pb	0	25.0	None	111
40	20° Pb	0	63.5	None	233
41	20° Pb	0	63.5	6 in. sand	228
42	20° Pb	0	63.5	9 in. sand	182
43	30° Pb	0	101.0	None	77
44	30° Pb	0	131.0	None	36
45	30° Pb	25	92.0	None	69
46	30° Pb	41	42.0	None	75
47	30° Pb	41	69.0	None	74
48	20° Pb	41	69.0	None	79
49	20° Pb	41	69.0	6 in. sand	22
50	20° Pb	41	69.0	9 in. sand	21
51	30° Pb	71	81.0	None	26
52	30° Pb	98	94.0	None	32
53	30° Pb	127	106.0	None	32
54	30° Pb	159	115.0	None	35
55	30° Pb	180	4.0	None	25
56	30° Pb	180	35.0	None	22
57	30° Pb	180	64.0	None	17
58	30° Pb	180	94.0	None	20

TABLE A-33

Collimator data, Doppler, 1,250 yards

(Area 7b, 1,500-ft. balloon, 160° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (ϕ) (deg.)	Attenuator thickness	Dose (r)
59	20° Pb	0	68	None	220.0
60	30° Pb	0	68	None	238.0
61	30° Pb	0	68	3 in. sand	165.0
62	30° Pb	0	68	6 in. sand	130.0
63	30° Pb	0	68	9 in. sand	96.0
64	45° None	0	68	None	285.0
65	30° Pb	0	31	None	49.0
66	30° Pb	37	47	None	40.0
67	30° Pb	39	72	None	27.0
68	30° Pb	39	72	3 in. sand	26.0
69	30° Pb	39	72	6 in. sand	20.0
70	30° Pb	25	96	None	21.0
71	30° Pb	0	105	None	> 20.0
72	45° None	62	106	None	24.0
73	45° None	79	63	None	10.5
74	45° None	111	15	None	32.0
75	30° Pb	25	124	None	> 20.0
76	45° None	180	43	None	> 20.0
77	45° None	128	67	None	> 20.0
78	45° None	180	85	None	> 20.0
79	45° None	147	114	None	14.5
80	45° None	107	106	None	10.0

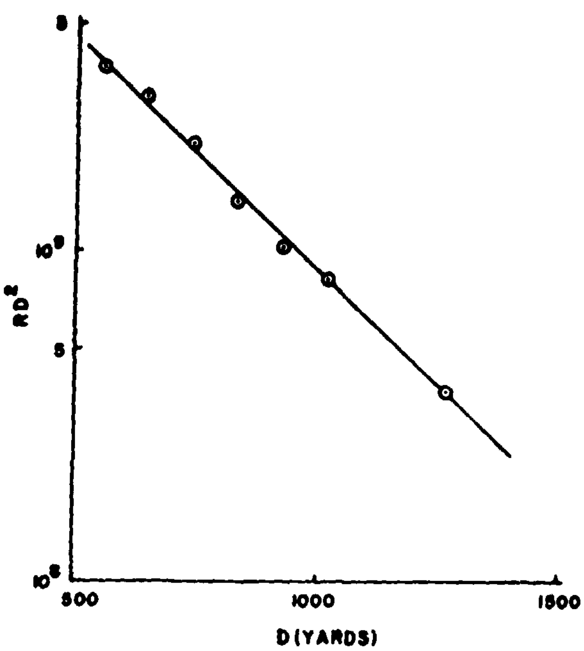

FIGURE A-12

Franklin Prime initial gamma radiation, 160°.

TABLE A-34

Goal-post data, Franklin Prime

(Area 7b, 750-ft. balloon, 160° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
500	560	3.14×10^5	11,625	3.65×10^9
600	650	4.23×10^5	7,050	2.98×10^9
700	744	5.54×10^5	3,840	2.13×10^9
800	839	7.04×10^5	2,000	1.41×10^9
900	934	8.67×10^5	1,175	1.02×10^9
1,000	1,031	1.063×10^6	770	8.20×10^8
1,250	1,275	1.63×10^6	232	3.78×10^8

TABLE A-35

Collimator data, Franklin Prime, 500 yards

(Area 7b, 750-ft. balloon, 160° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (ø) (deg.)	Attenuator thickness	Dose (r)
A	No gamma insert	0	180.0	None	27
B	45° None	0	180.0	None	16
C	Pb liner only	0	180.0	None	510
D	45° None	180	71.5	None	198
E	20° Pb	180	71.5	None	107
F	30° Pb	180	71.5	None	143

TABLE A-36

Collimator data, Franklin Prime, 750 yards

(Area 7b, 750-ft. balloon, 160° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (φ) (deg.)	Attenuator thickness	Dose (r)
11	20° Pb	0	71.5	None	860.0
12	20° Pb	0	71.5	6 in. sand	830.0
13	20° Pb	0	52.0	None	545.0
14	20° Pb	0	52.0	6 in. sand	210.0
15	20° Pb	0	90.0	None	288.0
16	20° Pb	0	90.0	6 in. sand	139.0
17	20° Pb	20	71.5	None	368.0
18	20° Pb	20	71.5	6 in. sand	148.0
19	30° Pb	41	71.5	None	110.0
20	30° Pb	41	71.5	6 in. sand	50.0
21	30° Pb	66	71.5	None	67.0
22	30° Pb	66	71.5	6 in. sand	45.0
23	45° None	66	71.5	None	116.0
24	45° None	66	71.5	6 in. sand	80.0
25	30° Pb	99	71.5	None	47.0
26	30° Pb	99	71.5	6 in. sand	22.0
27	30° Pb	130	[illegible]	None	30.0
28	30° Pb	130	71.5	6 in. sand	[illegible]
29	30° Pb	161	71.5	None	34.0
30	30° Pb	161	71.5	6 in. sand	26.5

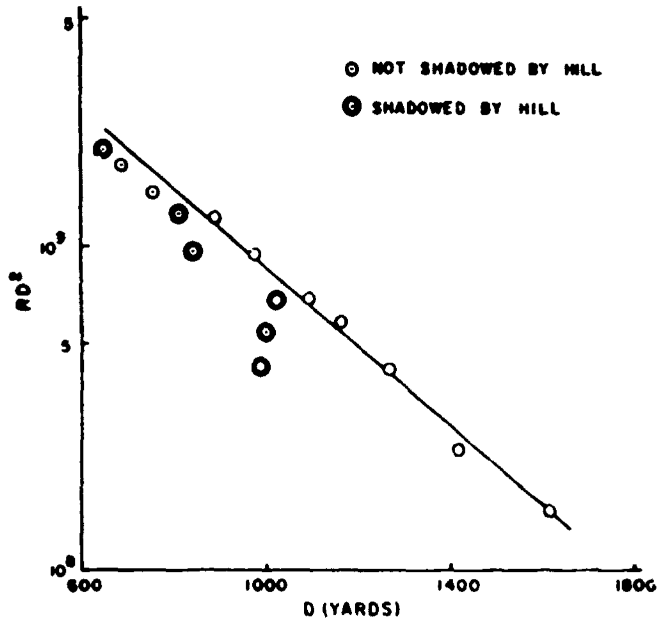

FIGURE A-13

Smoky initial gamma radiation east line, 90°.

TABLE A-37

Goal-post data, Smoky

(Area 2c, 700-ft. tower, east line, 90° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
610	651	4.24×10^5	47,000	1.99×10^{10}
660	691	4.78×10^5	37,000	1.77×10^{10}
725	756	5.72×10^5	25,000	1.43×10^{10}
780	810	6.56×10^5	19,000	1.25×10^{10}
810	841	7.07×10^5	13,500	9.54×10^9
860	887	7.87×10^5	15,500	1.22×10^{10}
955	980	9.60×10^5	9,800	9.41×10^9
965	990	9.80×10^5	4,300	4.21×10^9
975	1,001	1.00×10^6	5,400	5.40×10^9
1,000	1,026	1.05×10^6	6,600	6.93×10^9
1,080	1,098	1.21×10^6	5,700	6.90×10^9
1,140	1,164	1.35×10^6	4,300	5.81×10^9
1,250	1,268	1.61×10^6	2,575	4.15×10^9
1,400	1,421	2.02×10^6	1,175	2.37×10^9
1,600	1,618	2.62×10^6	580	1.52×10^9
1,800	1,816	3.30×10^6	230	7.60×10^8

TABLE A-38

Goal-post data, Smoky*

(Area 2c, 700-ft. tower, north line, 0^{o} Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
450	498			Lost
600	629			Lost
700	719			Lost
825	833			Lost
900	903	8.15×10^5	12,750	1.039×10^{10}
930	933	8.70×10^5	12,750	1.11×10^{10}
1,000	1,003	1.01×10^6	12,300	1.24×10^{10}
1,100	1,106	1.22×10^6	2,080	2.54×10^9
1,200	1,209			Lost
1,300	1,309			Lost

*Not plotted, results contaminated by fallout, recovery D + 3 days.

TABLE A-39

Goal-post data, Smoky*

(Area 2c, 700-ft. tower, south line, 180° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
400	466			Lost
600	649			Lost
800	841			Lost
1,000	1,034			Lost
1,200	1,229	1.51×10^6	2,870	4.33×10^9
1,400	1,426	2.03×10^6	2,235	4.54×10^9
1,500	1,525	2.33×10^6	1,700	3.96×10^9
1,600	1,623	2.63×10^6	1,480	3.89×10^9
1,700	1,722	2.97×10^6	1,420	4.22×10^9
1,800	1,821	3.32×10^6	1,150	3.82×10^9
1,900	1,920	3.69×10^6	1,325	4.89×10^9
2,000	2,019	4.08×10^6	1,000	4.08×10^9

*Not plotted, results contaminated by fallout, recovery D + 3 days.

TABLE A-40

Smoky shot slant-range calculation, east line

Dist. from GZ (yd.)	Elevation above GZ (ft.)	Slant range (yd.)
400	+30	458
500	+45	545
565	+38	607
610	+21	651
660	+44	691
725	+56	756
780	+46	810
811	+36	841
860	+48	887
955	+41	980
965	+30	990
975	+16	1,001
1,000	+12	1,026
1,080	+21	1,098
1,140	+ 2	1,164
1,250	-20	1,268
1,400	-36	1,421
1,600	-30	1,618
1,800	-20	1,816

TABLE A-41

Smoky shot slant-range calculation, south line

Dist. from GZ (yd.)	Elevation above GZ (ft.)	Slant range (yd.)
400	- 20	466
600	- 60	649
800	- 80	841
1,000	- 95	1,034
1,200	-105	1,229
1,400	-120	1,426
1,500	-120	1,525
1,600	-125	1,623
1,700	-125	1,722
1,800	-130	1,821
1,900	-130	1,920
2,000	-135	2,019

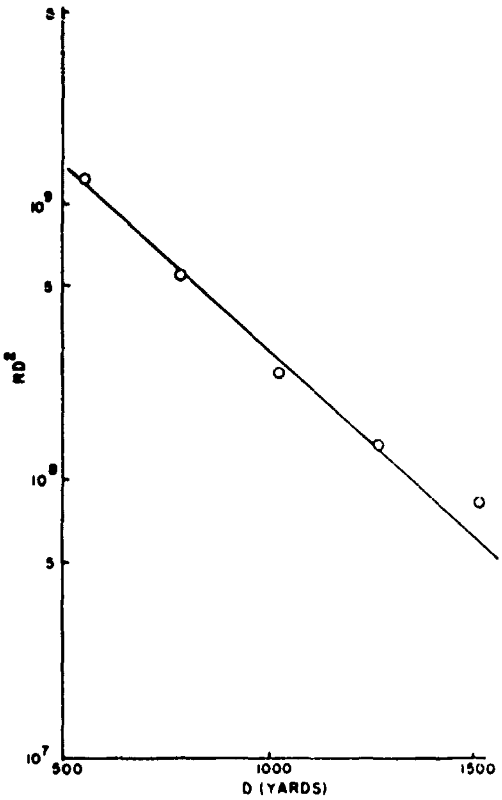

FIGURE A-14

La Place initial gamma radiation, 160^o.

TABLE A-42

Goal-post data, La Place

(Area 7b, 750-ft. balloon, 160^o Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
500	559	3.12×10^5	3,900	1.25×10^9
750	790	6.24×10^5	890	5.46×10^8
1,000	1,030	1.06×10^6	230	2.44×10^8
1,250	1,275	1.625×10^6	82	1.35×10^8
1,500	1,520	2.31×10^6	36	8.3×10^7

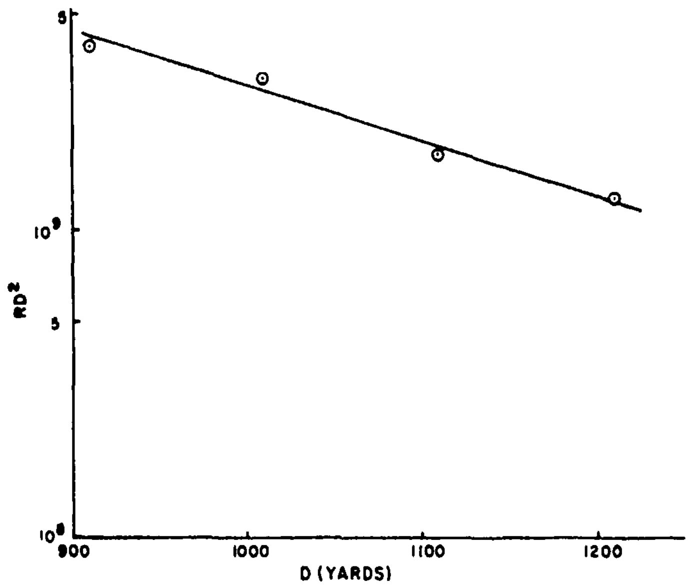

FIGURE A-15

Fizeau initial gamma radiation, 200° Az.

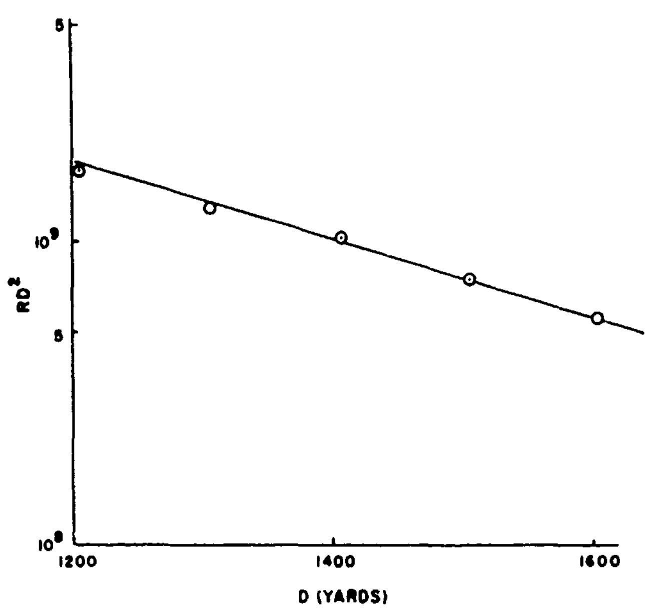

FIGURE A-16

Fizeau initial gamma radiation, 185° Az.

TABLE A-43

Goal-post data, Fizeau

(Area 3b, 500-ft. tower)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
		House line (200° Az.)		
900	911	8.28×10^5	4,750	3.93×10^9
1,000	1,010	1.02×10^6	3,000	3.06×10^9
1,100	1,110	1.23×10^6	1,430	1.76×10^9
1,200	1,210	1.47×10^6	825	1.26×10^9
		Collimator line (195° Az.)		
1,200	1,210	1.47×10^6	1,080	1.59×10^9
		Animal line (185° Az.)		
1,200	1,210	1.47×10^6	1,160	1.71×10^9
1,300	1,310	1.72×10^6	750	1.29×10^9
1,400	1,410	1.99×10^6	505	1.09×10^9
1,500	1,509	2.28×10^6	325	7.41×10^8
1,600	1,608	2.59×10^6	216	5.6×10^8

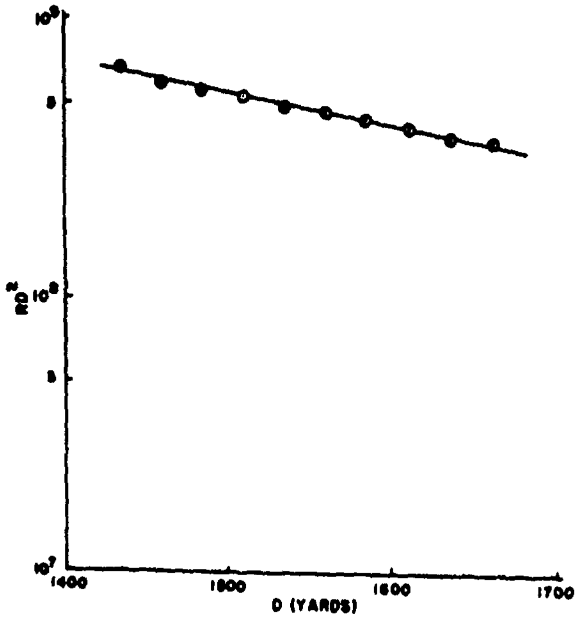

FIGURE A-17

Fizeau initial gamma radiation. Monkey exposures - 185° Az.

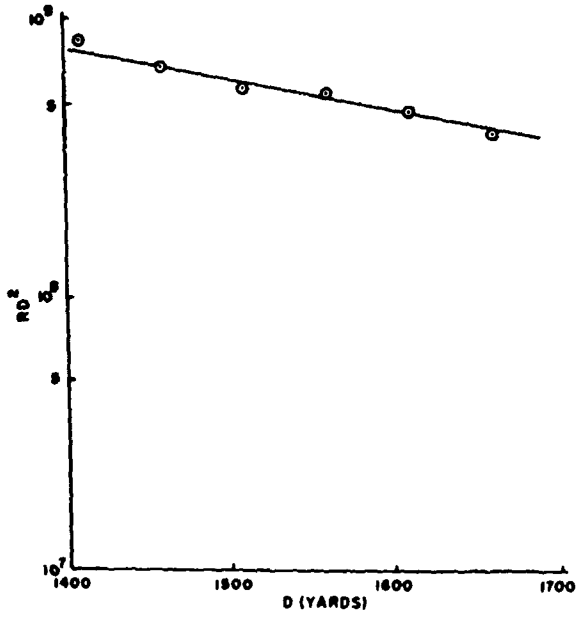

FIGURE A-18

Fizeau initial gamma radiation Burro exposures - 185° Az.

TABLE A-44

Monkey exposure data, Fizeau

(Area 3b, 500-ft. tower, 185° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
1,425	1,435	2.06×10^6	323	6.66×10^8
1,450	1,460	2.13×10^6	276	5.88×10^8
1,475	1,484	2.20×10^6	254	5.59×10^8
1,500	1,509	2.28×10^6	227	5.18×10^8
1,525	1,534	2.36×10^6	204	4.76×10^8
1,550	1,559	2.43×10^6	187	4.54×10^8
1,575	1,583	2.51×10^6	169	4.24×10^8
1,600	1,608	2.59×10^6	154	3.99×10^8
1,625	1,633	2.67×10^6	138	3.68×10^8
1,650	1,658	2.75×10^6	128	3.52×10^8

TABLE A-45

Burro exposure data, Fizeau

(Area 3b, 500-ft. tower, 185^{o} Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
1,400	1,410	1.99×10^6	420	8.37×10^8
1,450	1,460	2.13×10^6	310	6.61×10^8
1,500	1,509	2.28×10^6	245	5.59×10^8
1,550	1,559	2.43×10^6	215	5.23×10^8
1,600	1,608	2.59×10^6	176	4.56×10^8
1,650	1,658	2.75×10^6	135	3.72×10^8

TABLE A-46

Burro implants, Fizeau

(Area 3b, 500-ft. tower, 185^{o} Az.)

Implant No.	Range (yd.)	Dose (r)
1	1,400	295
2	1,400	421
3	1,400	298
4	1,400	405
5	1,400	420
6	1,400	410

TABLE A-47

House data, Fizeau

(Area 3b, 500-ft. tower, $\approx 200^{\circ}$ Az.)

Location No.	Can No.	Dose (r)
H-I-1	112	2,250
H-I-2	113	2,250
H-I-3	114	3,050
H-I-4	115	2,500
H-I-5	116	2,450
H-I-6	117	1,650
H-I-7	118	2,450
H-I-8	119	2,175
H-I-9	120	2,100
H-I-10	121	1,660
H-I-11	122	1,875
H-I-12	123	1,950
H-I-13	124	1,700
H-I-14	125	2,250
H-I-15	126	1,675

TABLE A-48

House data, Fizeau

(Area 3b, 500-ft. tower, $\approx 200^{\circ}$ Az.)

Location No.	Can No.	Dose, r
H-II-1	127	2,200
H-II-2	128	1,900
H-II-3	129	2,025
H-II-4	130	1,875
H-II-5	131	1,925
H-II-6	132	1,925
H-II-7	133	2,225
H-II-8	134	2,250
H-II-9	135	2,590
H-II-10	136	2,450
H-II-11	137	2,650
H-II-12	138	2,550
H-II-13	139	2,500
H-II-14	140	2,315
H-II-15	141	2,225

TABLE A-49

Collimator data, Fizeau, 1,000 yards

(Area 3b, 500-ft, tower, 195° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
11	20° Pb	0	80.5	None	1,050
12	20° Pb	0	80.5	3 in. sand	720
13	20° Pb	0	80.5	6 in. sand	350
14	20° Pb	0	80.5	9 in. sand	340
15	30° Pb	0	80.5	None	950
16	45° None	0	80.5	None	1,350
17	45° None	0	80.5	3 in. sand	900
18	45° None	0	80.5	6 in. sand	720
19	45° None	0	80.5	9 in. sand	440
20	30° Pb	0	43.0	None	163
21	30° Pb	33	59.0	None	106
22	30° Pb	36	89.0	None	107
23	30° Pb	36	89.0	3 in. sand	49
24	30° Pb	36	89.0	6 in. sand	51
25	30° Pb	36	89.0	9 in. sand	51
26	30° Pb	18	113.0	None	78
27	30° Pb	0	13.0	None	10
28	30° Pb	62	32.0	None	<10
29	30° Pb	67	60.0	None	61
30	30° Pb	67	60.0	3 in. sand	48
31	30° Pb	67	60.0	6 in. sand	37
32	30° Pb	67	60.0	9 in. sand	49

TABLE A-50

Collimator data, Fizeau, 1,000 yards

(Area 3b, 500-ft. tower, 195° Az.)

Coll. No.	Insert	Az. (θ) (deg.)	El. (Ø) (deg.)	Attenuator thickness	Dose (r)
33	30° Pb	67	90	None	54.0
34	30° Pb	92	95	None	43.0
35	30° Pb	92	125	None	28.0
36	30° Pb	57	119	None	37.0
37	30° Pb	180	16	None	< 5.0
38	30° Pb	115	35	None	23.0
39	30° Pb	102	64	None	36.0
40	30° Pb	102	64	3 in. sand	< 5.0
41	30° Pb	102	64	6 in. sand	< 5.0
42	30° Pb	102	64	9 in. sand	12.0
43	30° Pb	180	47	None	17.5
44	30° Pb	145	59	None	16.0
45	30° Pb	128	85	None	25.0
46	30° Pb	128	85	3 in. sand	19.0
47	30° Pb	128	85	6 in. sand	15.0
48	30° Pb	128	85	9 in. sand	< 5.0
49	30° Pb	125	115	None	40.0
50	20° Pb	180	78	None	< 5.0
51	20° Pb	180	78	3 in. sand	<10.0
52	20° Pb	180	78	6 in. sand	<10.0
53	20° Pb	180	78	9 in. sand	<10.0
54	30° Pb	156	98	None	40.0
55	30° Pb	180	123	None	41.0

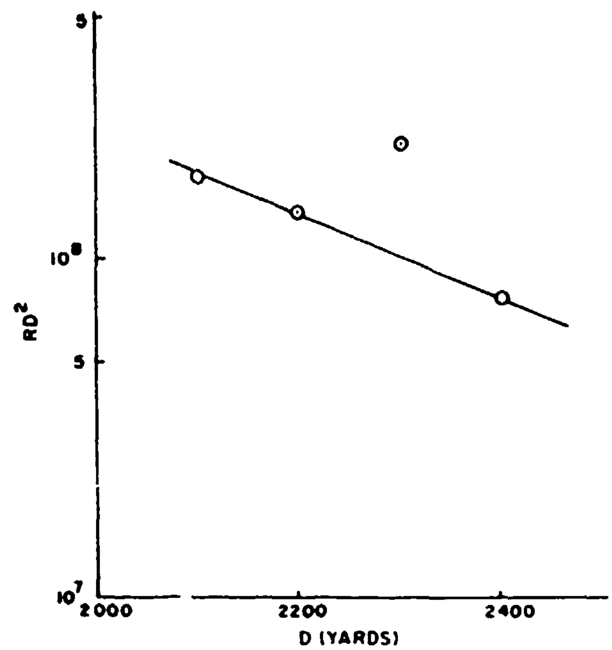

FIGURE A-19

Charleston initial gamma radiation - 120° Az.

TABLE A-51

Goal-post data, Charleston

(Area 7b, 1,500-ft. balloon, 120° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
2,100	2,102	4.4×10^6	39.0	1.72×10^8
2,200	2,201	4.84×10^6	28.5	1.37×10^8
2,300	2,391	5.29×10^6	41.5	2.19×10^8
2,400	2,400	5.76×10^6	13.5	7.78×10^7
2,500	2,500	6.25×10^6	<10.0	

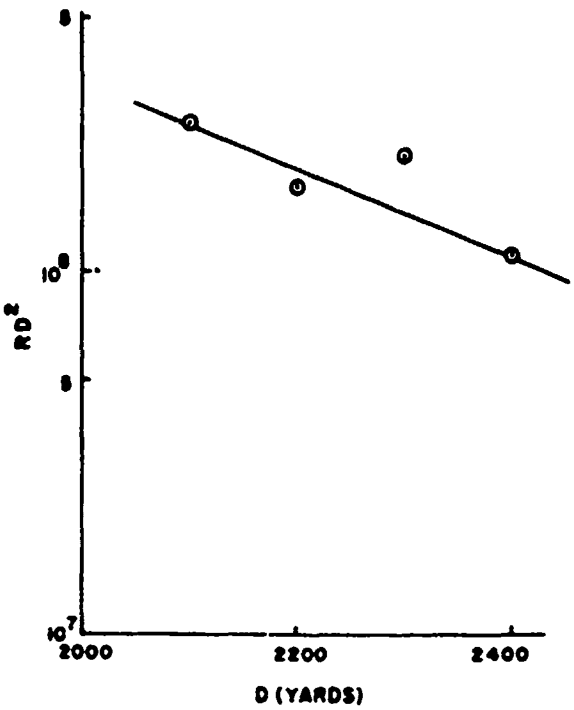

FIGURE A-20

Charleston initial gamma radiation 127° Az.

TABLE A-52

Goal-post data, Charleston

(Area 7b, 1,500-ft. balloon, 127° Az.)

Range (yd.)	Slant range (D) (yd.)	D^2	Dose (r)	RD^2
2,100	2,102	4.4×10^6	58	2.56×10^8
2,200	2,201	4.84×10^6	35	1.69×10^8
2,300	2,301	5.29×10^6	39	2.05×10^8
2,400	2,400	5.76×10^6	19	1.09×10^8
2,500	2,500	6.25×10^6	<10	9.4×1[illegible]

TABLE A-53

Collimator data, Charleston

(Area 7b, 1,500-ft. balloon, 127° Az.)

Coll. No.	Dose (r)
1	<10

TABLE A-54

Summary of relaxation lengths

Device and Az. of measurement	KT	Weather data		Slope and relaxation lengths from least square analysis	
		Pressure (mb.)	Temperature (^{o} C.)	Slope	Relaxation length
1. Franklin					
$342^{o}19'56''$	0.138	861	22.2	1.49×10^{-3}	288
195^{o}	0.138	861	22.2	1.186×10^{-3}	361
2. Wilson					
120^{o}	10.0	865	20.3	1.192×10^{-3}	359
204^{o}	10.0	865	20.3	1.373×10^{-3}	312
120^{o} (monkey line)	10.0	865	20.3	1.393×10^{-3}	303
3. Priscilla					
270^{o}	36.5	886.7	24.0	1.457×10^{-3}	[illegible]
4. Hood					
130^{o}	77.0	821	26.9	1.20×10^{-3}	354
5. Diablo					
90^{o}	17.0	849	23.8	1.192×10^{-3}	359
6. Kepler					
90^{o}	10.0	850	21.2	1.408×10^{-3}	300
7. Stokes					
160^{o}	18.5	825	18.3	1.394×10^{-3}	307
8. Doppler					
160^{o}	10.5	832	22.0	1.43×10^{-3}	298
9. Franklin Prime					
160^{o}	4.75	844	14.3	1.411×10^{-3}	303
10. Smoky					
90^{o}	43.0	844	15.2	1.215×10^{-3}	351
11. LaPlace					
160^{o}	1.25	849	25.4	1.229×10^{-3}	344
12. Fizeau					
200^{o}	11.0	865	22.0	1.726×10^{-3}	250
185^{o}	11.0	865	22.0	1.218×10^{-3}	347
185^{o} (m.l.)*	11.0	865	22.0	1.202×10^{-3}	351
185^{o} (b.l.)*	11.0	865	22.0	1.432×10^{-3}	289
13. Charleston					
120^{o}	11.0	829	18.5	1.17×10^{-3}	362
127^{o}	11.0	829	18.5	1.229×10^{-3}	347

*m.l. = Monkey line.
*b.l. = Burro line.

TABLE A-55

Summary of radiation "O" intercepts per KT

Device and Az. of measurement	KT	R_oW_i from least square analysis	R_o from least square analysis
1. Franklin			
342°19'56"	0.138	8.65×10^8	6.268×10^9
195°	0.138	4.853×10^8	3.517×10^9
2. Wilson			
120°	10.0	4.41×10^{10}	4.41×10^9
204°	10.0	6.282×10^{10}	6.282×10^9
120° (monkey line)	10.0	9.906×10^{10}	9.906×10^9
3. Priscilla			
270°	36.5	2.20×10^{11}	6.047×10^9
4. Hood			
120°	77.0	4.625×10^{11}	6.006×10^9
5. Diablo			
90°	17.0	3.099×10^{10}	1.823×10^9
6. Kepler			
90°	10.0	9.945×10^9	9.94×10^8
7. Stokes			
160°	18.5	1.439×10^{10}	6.15×10^9
8. Doppler			
160°	10.5	8.86×10^{10}	8.438×10^9
9. Franklin Prime			
160°	4.75	2.29×10^{10}	4.834×10^9
10. Smoky			
90°	43.0	1.35×10^{11}	3.14×10^9
11. La Place			
160°	1.25	5.325×10^9	4.26×10^9
12. Fizeau			
200°	11.0	1.53×10^{11}	1.391×10^{10}
185°	11.0	5.20×10^{10}	4.72×10^9
185° (monkey line)	11.0	3.40×10^{10}	3.09×10^9
185° (burro line)	11.0	8.54×10^{11}	7.682×10^9
13. Charleston			
120°	11.0	5.03×10^{10}	4.573×10^9
127°	11.0	9.93×10^{10}	9.027×10^9